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August 27, 1997

RECEIVED
AUG 27 1997
FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

William Caton, Secretary
Federal Communications Commission
1919 M. Street, NW
Washington, D.C. 20554

Re: *DIRECTV Enterprises, Inc.; ET 97-99, RM No. 9118, DA 97-1285; "Technical Response to Teligent DEMS/BSS Interference Analysis and Proposed Solution"*; ***EX PARTE***

Dear Mr. Caton:

Attached is a paper prepared by DIRECTV entitled "Technical Response to Teligent DEMS/BSS Interference Analysis and Proposed Solution," in which DIRECTV outlines an approach for resolving interference issues with DEMS licensees at 24 GHz, and responds to technical analyses set forth in certain DEMS licensees' Joint Opposition to Petition for Rulemaking of DIRECTV Enterprises, Inc., RM No. 9118, filed July 31, 1997.

Rather than adopt the DEMS licensees' approach of viewing BSS system/DEMS co-existence in terms of mandatory separation distances, DIRECTV believes that a coordination approach based on determining an appropriate signal power flux density imposed at the DEMS node site vis-à-vis BSS uplinks, combined with individualized shielding efforts in particular markets, would be a workable and productive method of resolving potential interference issues between BSS operations and DEMS licensees in the 24 GHz frequency band. Of course, by submitting this analysis, DIRECTV does not concede that any of the FCC's actions in relocating DEMS licensees to date are legally supportable, or that the 24 GHz band is the proper spectrum in which to relocate DEMS if nationwide relocation from 18 GHz in fact is even necessary.

No. of Copies rec'd 0+2
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Thank you for your consideration. Please contact the undersigned should you have any questions. Copies of this submission are being provided to Commission staff and parties on the attached service list.

Very truly yours,

John P. Janka
James H. Barker

Attachment

TECHNICAL RESPONSE TO TELIGENT DEMS/BSS INTERFERENCE ANALYSIS AND PROPOSED SOLUTION

August 27, 1997

DIRECTV ENTERPRISES, INC.

TECHNICAL RESPONSE TO TELIGENT DEMS/BSS INTERFERENCE ANALYSIS AND PROPOSED SOLUTION

August 27, 1997

DIRECTV ENTERPRISES, INC.

1. Introduction

This paper responds to Teligent's analysis of the interference potential from proposed BSS feeder links at 25.05-25.25 GHz into DEMS nodal stations and proposes an alternate solution to the establishment of large geographic exclusion zones where BSS feeder links may not operate, as Teligent has proposed. Teligent's analysis is contained in the Joint Opposition to Petition for Rulemaking of DIRECTV Enterprises, Inc. in FCC RM 9118 (July 31, 1997). *In the final analysis, DIRECTV shows (i) how it is possible for BSS feeder links and DEMS nodes to share spectrum on a cofrequency basis at distances in the range of 2/10 of a mile, and (ii) why the 100-300 mile separation distances that Teligent proposes are simply unnecessary to ensure the successful coexistence and operation of DEMS and BSS systems.*

DIRECTV has maintained that the interference potential from BSS feeder links into the DEMS service will not preclude shared use of the 200 MHz of spectrum from 25.05 to 25.25 GHz in the same geographic vicinity, as long as the affected parties are committed to maximizing use of the limited spectrum resource. Teligent contends that the proposed BSS feeder links will present an unacceptable potential for interference if they are located within 100-300 miles of a DEMS receiver. Such a limitation would preclude BSS feeder links from being located within a reasonable distance of a major metropolitan area, and therefore would be unacceptable to a BSS operator.

The fundamental flaw in Teligent's analysis is its basic premise that the terms for BSS feeder link and DEMS coexistence should be based on the minimum separation distance that is needed to afford protection to DEMS receivers in a theoretical worst case interference analysis. To the contrary, there is no need to establish "stay out zones" for BSS uplinks as long as an appropriate signal power flux density limit is imposed at the DEMS node site with respect to the signal emitted by the BSS uplink. Such an approach would provide the BSS uplink operator with many different ways to reduce its emissions in the direction of the DEMS nodal site, while facilitating the cofrequency operation of BSS uplink sites in major metropolitan areas, and still fully protecting closely neighboring DEMS operations.

2. Method of Analysis

The maximum allowable interference level from a BSS uplink into a DEMS nodal receiver is first calculated simply by adding an acceptable margin to the DEMS receive system noise floor. Although DIRECTV's parameter values are different from Teligent's most recent analysis for reasons explained below, the concept is the same. Using a DEMS nodal noise temperature of 30.6 dB°K, the DEMS noise floor is established at -198.0 dB°K (-228.6 + 30.6). Adding an Io/No margin of -12 dB, the maximum allowed interference level is -210.0 dBW/Hz, which DIRECTV uses as the maximum interference level from a satellite uplink station (line 13 of attached spreadsheet). To get power flux density, one must "back out" (subtract) the receive antenna gain and the isotropic area. This yields a maximum power flux density at the DEMS node of -176.6 dBW/m^2/Hz (-210 - 16 - (-49.4)).

DIRECTV maintains that with a maximum BSS uplink interference power defined, appropriate interference mitigation techniques can be employed on a case-by-case basis to allow maximum flexibility for the location of both services.

3. INTERFERENCE MITIGATION TECHNIQUES

Less than a year ago, when Teligent's affiliates were encouraging the use of sharing techniques to facilitate co-frequency use of the spectrum at 18 GHz by DEMS and the satellite services proposed by Teledesic, Teligent advocated the use of standard mitigation techniques, such as antenna shielding, to reduce the possibility of satellite receivers experiencing unacceptable interference from DEMS transmitters. See "Coordination Approaches and Interference Mitigation Techniques for the 18.8-19.3 GHz Band," December 16, 1996, prepared for Microwave Services, Inc. and Digital Services, Inc. (attached as Exhibit A). Curiously, now that the tables are turned and Teligent is the potential interference "victim," Teligent now does not even consider the effect of mitigation techniques to limit the potential for interference from BSS feeder links.

Only nine months ago, Teligent's affiliates argued that if interference is predicted to occur, there are a number of choices that are available to the potential interferor: (i) move the proposed transmitter to a different location at the site to take advantage of natural shielding, such as topography or preexisting building blockage, (ii) add shielding to the antenna of either the transmitter or the affected receiver, or (iii) coordinate with the potentially affected party through the exchange of detailed system information.

DIRECTV does not intend to provide a comprehensive analysis of mitigation techniques in this paper. A brief discussion of potential solutions will suffice to make the point that mitigation techniques exist that will greatly reduce the potential interference into a DEMS receiver from a BSS feeder link station. These mitigation techniques include the following, which can be used alone or in combination to achieve the desired level of mitigation:

- Existing Shielding: Use of existing shielding can provide sufficient attenuation of interfering signals to allow sharing of frequencies in many areas. As stated in the report sponsored by Teligent's affiliates referenced above (Exhibit A at 4-5):

  > "Physical separation employs shielding to assure that the signal strength of the wanted signal is much higher at the receive location than the signal strength of the unwanted signal. Most shielding occurs naturally, rather than being installed to solve a specific interference problem. The curvature of the earth provides

> shielding; a radio signal that propagates along a straight line is blocked by the curvature of the earth. Irregular terrain provides shielding, and the magnitude of this shielding can be calculated using digitized terrain maps and commonly applied methods of evaluating losses on diffraction paths."
>
> "Buildings cause shielding, but until recently databases did not exist to support calculations of the shielding caused by buildings. Now, however, there are databases of building locations, shapes and heights for use in signal propagation calculations."
>
> "Preliminary analyses of such data show that in Washington, DC, blockage by intervening buildings results in a relatively high likelihood of path blockage between any two buildings in town."
>
> "Foliage losses also contribute to isolation between stations, but the effects are seasonally and environmentally dependent. Nonetheless, any predicted mitigation losses due to earth curvature, terrain and building blockage will be enhanced in some cases due to foliage losses."

- Additional Shielding: Artificial shielding can be added at the feeder link site to reduce the RF energy incident at a DEMS node. The use of shielding fences and berms (and/or recessing the feeder link antenna into the ground) are methods that can be employed by the feeder link operator to mitigate the potential interference.

  Minimal shielding methods such as a metallic fence designed to reflect RF energy away from the potential victim can be expected to provide at least 15 dB of attenuation. More advanced shielding methods such as absorptive shielding, where rubber is treated with ferrous-oxide (to convert RF energy into heat) can be used as a stand-alone shield or in combination with reflective shielding to provide 30 dB or more of attenuation. Berms have been estimated to provide more than 40 dB of interference protection, and would be the optimum technique to use where the two services are located close to each other.

- Information Sharing: As advocated in this same report, the sharing of key information such as transmitter and receiver locations, power levels, antenna patterns and configurations (direction of beam peaks), is essential to spectrum sharing. DIRECTV supports this method.

4. POINTS OF ISSUE WITH TELIGENT'S ANALYSIS

As noted above, Teligent's focus on separation distance alone proceeds from a false premise. In addition, Teligent's conclusion that separation distances of 94 to 316 miles are required is based on analysis that ignores or exaggerates several critical parameters and thereby vastly overstates the scope of interference potential. Even considering the effect of the move of

DEMS from 18 to 25 GHz, Teligent offers no explanation of why it has altered the parameters that it previously used for analyzing the potential for interference into DEMS from satellite services when Teligent was attempting to prove that DEMS licensees could coexist with the Teledesic system. The discrepancies in Teligent's analysis are delineated below:

- Teligent's claim for separation distances of 94 to 316 miles ignores the effect of the radio horizon (radio waves at 25 GHz will not bend significantly over the horizon). Teligent plans to mount nodal antennas on building tops. If, for example, a nodal receive antenna were mounted on the World Trade Center (Promenade Deck - ht: 1377 ft.), the radio horizon is 45.4 miles. Proposing separation distances that extend beyond the radio horizon does not make sense. Using a more realistic node height of 200 feet, the radio horizon is 17.3 miles. Yet even that distance is inappropriate as a "stay out zone" because interference mitigation techniques can almost eliminate uplink interference in the "worst case" direction.

- In a previous analysis submitted to the Commission by Teligent's affiliates when Teligent was attempting to demonstrate its sharing capabilities ("Setting the Record Straight: Interference Issues Between 18 GHz DEMS and the Proposed Teledesic NGSO-FSS Satellite System," October 11, 1996, by Eric N. Barnhart), Teligent's sample link budget used a receive antenna gain for the nodal station of 16 dBi, which corresponds to a beamwidth of approximately 120 degrees. Teligent's analysis now uses a significantly higher nodal receive antenna gain of 23.8 dBi, which corresponds to a beamwidth of only about 20 degrees. A 120 degree sector antenna at 25 GHz will have the same gain as a 120 degree antenna at 18 GHz[1]. Use of a higher receive gain in this case (where Teligent does not want to share) increases the separation distance that Teligent calculated when it wanted to share.

- The system noise temperature that Teligent uses also has changed without any explanation. While Teligent used 30.6 dB°K last October in analyzing the Teledesic case, it now employs a value of 29.1 dB°K. The use of a lower noise temperature in Teligent's analysis makes the DEMS system seem more susceptible to interference. Typically, system noise temperature increases with frequency when similar components are used. This is the case because the source resistance of a device increases as the wavelength decreases. Thus, one would expect a higher, not a lower, system noise temperature at 24 GHz.

- Teligent uses an "Io/No Allowable to FSS Interference" of -15 dB, which is to say that it demands that interfering signals be 15 dB below the DEMS noise floor. DIRECTV believes that a more reasonable value used in Io/No analyses to be -12 dB. DIRECTV believes that -12 dB offers more than a sufficient margin to avoid

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1 It is true that, for a given antenna size, higher frequencies produce higher gains. But for a given beamwidth, gain is independent of frequency (because a smaller antenna will be needed to provide the same beamwidth at the higher frequency).

interference, without having any effect on link availability. This corresponds to only 6.3% added noise to the DEMS system, compared to using a - 15 dB value.

- Teligent has completely ignored the effect of atmospheric attenuation in its analysis. Specifically, water vapor absorption at 25 GHz causes approximately 0.15 dB/km (0.24 dB/mi) of attenuation. At a distance of 94 miles, as in Teligent's Case 6, water vapor absorption would cause over 22 dB of attenuation to the interfering signal, thus significantly decreasing the potential for interference from a BSS uplink.

5. Detailed Analysis

As set forth below, Teligent's analysis is misleading in many respects and overstates the scope of the potential problem. Moreover, it ignores the use of interference mitigation techniques that can be used to reduce the zone of potential interference around the BSS feeder link site. This approach is seriously flawed in that it sets hard limits in miles where the key constraint should be power flux density levels from a BSS feeder link into a DEMS node.

A power flux density (PFD) limit of -176.6 dBW/m^2/Hz at a DEMS node provides for an Io/No of -12 dB with a DEMS nodal antenna receive gain of 16 dBi and a system noise temperature of 30.6 dB°K. A BSS feeder link would be designed to meet the PFD limits at the nearest DEMS node. Field strength measurements could be made to ensure that these limits are met before operation of the feeder link. This method of coordination provides for maximum flexibility of location for both BSS feeder links and DEMS service areas.

DIRECTV has prepared an Io/No interference analysis to determine the severity of the interference from a proposed BSS feeder link into a DEMS system. Included in this report are four interference cases and the potential interference zones associated with each set of parameters that meet the sample PFD limit of - 176.6 dBw/m^2/Hz.

Case 1: Teligent's Case 6 from their July 31, 1997 filing in this matter is provided for a comparison with DIRECTV's results.

Case 2: Assumes all of Teligent's parameter values from their Case 6 analysis, but accounts for atmospheric losses that naturally mitigate the interfering signal. Merely adding the effects of water vapor absorption at 25 GHz decreases Teligent's proposed separation distance from 94 to 36 miles. This case illustrates that if Teligent had simply accounted for the well known atmospheric effects at 25 GHz, Teligent's proposed separation distances would decrease dramatically, even without considering the significant ameliorating effects of other mitigation techniques.

Case 3: DIRECTV's analysis using shielding at the feeder link to provide 40 dB of protection, and a more reasonable Io/No of-12 dB. **The coordination distance reduces to 0.2 miles.**

6. Conclusion

Spectrum sharing between DEMS and BSS feeder links in the 25.05 to 25.25 GHz band is not only possible, but quite feasible with the cooperation of the service providers. Several types of mitigation techniques would facilitate sharing and should be explored.

As evident by the DIRECTV analysis, with only minimal shielding, whether from natural or artificial means, BSS uplinks can be located very close to DEMS modes, yet still meet a PFD limit that allows DEMS systems to operate without unacceptable interference from neighboring BSS uplinks. Thus, BSS uplink and DEMS coexistence is possible in neighboring areas.

Table 1: Io/No Interference Analysis Between BSS Feeder Links and DEMS Stations

	Parameter	Units	Case 1: Teligent Most Recent Analysis	Case 2: Teligent Analysis Plus Atmos. Atten.	Case 3: DIRECTV Analysis With Shielding
1	DTV Uplink EIRP (on-axis)	dBW	76.1	76.1	76.1
2	Off-Axis Loss	dB	-76.6	-76.6	-76.6
3	Shielding	dB	0.0	0.0	-40.0
4	Bandwidth (24 MHz)	dB-Hz	-73.8	-73.8	-73.8
5	Uplink EIRP Towards Horizon	dBW/Hz	-74.3	-74.3	-114.3
6					
7	DEMS System Noise Temp.	dBK	29.1	29.1	30.6
8	Boltzmann's Constant	dBW/K/Hz	-228.6	-228.6	-228.6
9	Noise Power Density (No)	dBW/Hz	-199.5	-199.5	-198.0
10					
11	Io/No Required	dB	-15.0	-15.0	-12.0
12					
13	Io Max from Satellite Uplink	dBW/Hz	-214.5	-214.5	-210.0
14					
15	DEMS Receive Antenna Gain Towards DTV Feede	dBi	23.8	23.8	16.0
16					
17	Isotropic Area	dB-m^2	-49.4	-49.4	-49.4
18					
19	Atmospheric Loss (at coordination distance in line 2	dB	0.0	-8.5	0.0
20					
21	Required Spreading Loss	dB/m^2	-114.6	-106.1	-62.3
22					
23	Coordination Distance	km	**151.5**	**56.9**	**0.4**
24		miles	**94.1**	**35.4**	**0.2**
25					
26	Power Flux Density at DEMS Node	dBW/m^2/H	**-188.9**	**-188.9**	**-176.6**

EXHIBIT A

Coordination Approaches and Interference Mitigation Techniques for the 18.8-19.3 GHz Band

Prepared for Microwave Services, Inc. and Digital Services Corp.

December 16, 1996

Introduction

Traditional frequency coordination among microwave systems, and between microwave and satellite systems permits different licensees to operate in the same frequency band. The sharing of technical information as well as information about the locations of existing transmitters and receivers facilitates coordination utilizing both physical separation and frequency separation. These same traditional approaches will provide sufficient isolation between 18 GHz DEMS microwave stations and Teledesic's proposed NGSO-FSS stations so that the two services may coordinate within that portion of the 18 GHz band in which they are co-primary. In addition, there are network control technologies and advanced signal processing techniques such as power control and more robust antenna implementations that will support new frequency coordination methods between DEMS and NGSO-FSS.

Actions of DEMS and NGSO-FSS Systems to Mitigate Interference

In light of the fact that DEMS systems are currently in place and continuing to be rolled-out, there are several specific DEMS and NGSO-FSS procedures that could enhance frequency coordination at the time when Teledesic begins offering service.

Traditional Approaches

Both DEMS and NGSO-FSS system operators can take the following actions to promote spectrum sharing and mitigate interference:

- **Information Sharing:** sharing of full information on stations between DEMS and NGSO-FSS licensees
- **Natural Means of Physical Separation:** use of an appropriate interference criteria based upon C/(N+I) in conjunction with building blockage data in frequency coordination calculations
- **Additional Means of Physical Separation:** adding shielding to block transmissions to or from specific directions

Enhanced Approaches

DEMS systems and NGSO-FSS systems can also take advantage of the following advanced methods to mitigate interference and enhance frequency coordination:

- **Power Control:** Both systems could adaptively reduce power during clear air and raise power during rain. DEMS systems could reduce power of User Stations according to distance from Nodal Station.
- **Antenna Pattern Improvement:** NGSO-FSS systems could employ antennas with better discrimination characteristics as well as with nulling in specific directions.
- **Frequency Separation, Coding and Filtering:** NGSO-FSS systems could employ channel plans that conform to terrestrial system channel plans so that the NGSO-FSS system could avoid frequencies already in use in certain areas but continue to operate on the remaining NGSO-FSS frequencies in those areas. In the alternative, such NGSO-FSS systems could employ interference mitigation coding or notch filtering that takes advantage of the relatively narrow bandwidth of DEMS signals compared to the Teledesic bandwidth of 500 MHz for its downlinks.

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In those rare instances where interference could not be mitigated, operating agreements between DEMS and NGSO-FSS systems could require DEMS systems to carry traffic for the NGSO-FSS system.

***

Traditional Approaches

Information Sharing

An essential element of frequency coordination is the sharing of licensee information such as transmitter and receiver locations and technical characteristics. In the past, one or more central clearinghouses of such data have been used as the basis of frequency coordination calculations. It is essential that licensees and applicants continue to have access to such information in the future.

The rules for DEMS do not require that DEMS licensees make available such information about DEMS User Stations to the public. While public availability of this information is not needed, licensees and applicants could voluntarily share the data among themselves. Since the number of affected licensees in the DEMS portion of the 18.8-19.3 GHz band is small, private contractual agreements among licensees would be sufficient to provide for such information sharing. DEMS Nodal Station information would continue to be part of the FCC's license data bases and would be available to the public.

With respect to NGSO-FSS earth stations, it is presumed that these earth stations will be licensed for the full 18.8-19.3 GHz band. Because a portion of this band will be shared with individually-licensed point-to-point microwave links, these earth stations will also have to be individually licensed and full details will have to appear in public records.

Coordination of New Transmitters. A new station must not cause interference to existing co-primary stations, and should not receive (or at least must accept) interference from existing stations. Since the 18.8-19.3 GHz band is now allocated on a co-primary basis to FS and FSS systems, this non-interference principle would apply both to new DEMS stations and new NGSO-FSS stations.

The frequency coordination process for a new DEMS station will operate as follows. First, the DEMS licensee will have access to a data base of licensed NGSO-FSS earth stations, as well as its own existing DEMS stations and (if near a SMSA boundary) stations of other DEMS licensees. The DEMS licensee will choose a tentative site and calculate whether a DEMS transmitter at that site will cause interference to any NGSO-FSS stations, and whether it will cause or receive interference from any "nearby" DEMS station. The calculation will take into account earth curvature blockage, terrain blockage and building blockage. It will also take into account any relevant technical details of the NGSO-FSS and DEMS stations.

The term "nearby station" is a way of describing the "coordination area" required by ITU-R recommendations and FCC Rules. But under these rules, coordination extends to and beyond distances where the likelihood of interference is negligible. See ITU-R IS.847. Thus, these calculations will typically cover many stations and will determine that interference is a possibility for only a very small number, if any.

Natural Means of Physical Separation

Physical separation employs shielding to assure that the signal strength of the wanted signal is much higher at the receive location than the signal strength of the unwanted signal. Most such shielding occurs naturally, rather than being installed to solve a specific interference problem. The curvature of the earth provides shielding; a radio signal that propagates along a straight lines is blocked by the curvature of the earth. Irregular terrain provides shielding, and the magnitude of this shielding can be calculated using digitized terrain maps and commonly applied methods of evaluating losses on diffraction paths.

Buildings cause shielding, but until recently data bases did not exist to support calculations of the shielding caused by buildings. Now, however, there are databases of building locations, shapes and heights for use in signal propagation calculations.

Preliminary analyses of such data show that, in Washington DC, blockage by intervening buildings results in a relatively high likelihood of path blockage between any two buildings in town. Thus, for any reasonable number of DEMS transmitters in town, a large number of buildings will be suitable antenna sites for Teledesic because rooftops of these buildings will be shielded from all DEMS transmissions.

Foliage losses also contribute to isolation between stations, but the effects are seasonally and environmentally dependent. Nonetheless, any predicted mitigation losses due to earth curvature, terrain and building blockage will be enhanced in some cases due to foliage losses.

Additional Means of Physical Separation

In addition to naturally occurring shielding, shielding may be added at antenna sites in the form of antenna shrouds or other structures. Teledesic's NGSO-FSS antennas, which are horizontally mounted phased arrays or mechanically steered dual antennas, can have shrouds, shielding matierals, or shielding walls erected around their perimeter or in the direction of the unwanted signal. Since the Teledesic antennas always have signal elevation angles exceeding 40 degrees, the height of the shielding wall could (for example) be set to achieve blockage of all signals at 20 degrees elevation or less. In this case, trigonometry shows that a shielding wall 3 feet from the antenna would need to be 1 foot high. In the 28 GHz Negotiated Rulemaking, the interference protection provided by shielding devices such as berms was estimated at more than 40 dB. Even minimal efforts at shielding are expected to produce isolation of 15 dB (ITU-R Report No. 831-1).

Antenna shielding can be quite inexpensive. For example, neoprene shielding material is available in sheets 1 foot X 1 foot X ½ inch thick, at a typical cost of $12 per square foot. Such shielding material could be installed on a frame like a "window sun visor" that allows the shielding to be configured at an appropriate direction and angle. Such a device need only be installed in the direction of the unwanted signal. Moreover combinations of shielding matieral and fiberglass shrouding could be employed. For antennas such as Teledesic's, installation should pose few problems.

Then, for example, if interference into an existing NGSO-FSS station is calculated to occur, the DEMS licensee has several choices. It may move its new station to a different location at the site or even to a different site. It may add shielding at the DEMS station site to block the signal in the direction of the NGSO-FSS station. It may offer to add shielding at the site of the NGSO-FSS. It may offer to move the NGSO-FSS station to take advantage of building blockage.

If a new NGSO-FSS station seeking to be installed in an area where a DEMS system is licensed, and if calculations show that interference to the NGSO-FSS station is likely, the station could be moved or shielded, or shielding could be added to the DEMS station. Or, the NGSO-FSS station could agree to accept such interference, which would be equivalent to accepting a secondary rather than co-primary allocation in the 100 MHz portion of the 500 MHz NGSO-FSS band that is shared with DEMS.

The general principle in frequency coordination is that reasonable offers to mitigate interference at the expense of the newcomer may not be unreasonably refused. The newcomer has the burden to mitigate interference, and is allowed to pay the expense of reasonable modifications to existing systems, if those modifications will allow the newcomers system to operate without interference. See Economic Techniques for Spectrum Management, by Carson E. Agnew, Math Tech, Inc., December 29, 1979, prepared for the Office of Plans and Policy of the Federal Communications Commission.

Interference Criteria and Calculated Separation Distances. The appropriate interference criterion for frequency sharing analyses is "C/(N+I)," the ratio of the wanted signal to the sum of noise and interference. This is because

> interference, in most practical circumstances, does not of itself cause errors but enhances the ability of thermal noise to cause errors.... ITU-R Report 877-1, p. 1.

In contrast, the use of "C/I," the ratio of the wanted signal to interference alone, is not appropriate.

The Teledesic system is designed to accept an interference criterion level of C/(N+I) = 6.5 dB. Calculations using this criterion and realistic estimates of DEMS power levels have shown that in clear air, and with no additional shielding, a DEMS nodal station can be as close as 28 feet from a Teledesic earth station and not cause interference to the earth station; in order to protect against interference even in heavy rain, assumed to occur only 0.1% of the time or about 1.5 minutes per day, DEMS nodal stations would have to be separated 300 feet from the Teledesic earth station. See "Setting the Record Straight: Interference Issues Between 18 GHz DEMS and the Proposed Teledesic NGSO-FSS Satellite System," October 11, 1996, prepared by Eric N. Barnhart.

Enhanced Approaches

While the previous sections suggest that the traditional frequency coordination methods based on physical separation and signal blockage will usually be sufficient to allow DEMS and NGSO-FSS to share the 18 GHz spectrum, there are additional techniques that can further enhance such sharing. These methods, which are described in the following paragraphs, include power control, antenna pattern improvement, and frequency separation.

Power Control

DEMS system design employs Nodal Stations with broad beam antennas to communicate with User Stations that are distributed throughout the area covered by the Nodal Station signal. The DEMS User Stations may be separated from the Nodal Station by distances that vary from a few hundred meters to a few kilometers. For a maximum DEMS cell size, the DEMS User Station is designed with a maximum transmit power that is just sufficient to "close the link" between the Nodal Station and User Station. User Stations that are closer to the Nodal Station than this hypothetical maximum distance may be installed with lower power levels. Frequency coordination calculations must take into account the actual (i.e lower than maximum) power levels of these close-in User Stations, rather than using some maximum transmit power level.

Fixed microwave systems have traditionally been designed to transmit with sufficient power to provide adequate margin against rain fades. This means that, in order to protect against a rain event that occurs (for example) 0.1% of the time, the transmitter is using a higher power than needed 99.9% of the time. New network control techniques make it possible to employ adaptive power control so that transmitters need raise their power levels only when rain events occur.

Adaptive power control could be used in DEMS networks as a way to mitigate interference into NGSO-FSS stations. This would mean that interference might occur only during infrequent rain events when the DEMS power levels were raised. Depending on the physical relationships between transmitters and receivers and the location of the rain, the rain itself could act as a shielding medium to reduce or eliminate interference during rain events, even if DEMS power levels were increased. Moreover, if the NGSO-FSS spacecraft system were designed with power control for its spot beam antennas, it could similarly raise its power levels during rain events to further reduce interference levels.

Antenna Pattern Improvement

Another form of shielding or physical separation is antenna directivity, which in effect blocks the signal transmission/reception in particular directions. Two specific types of improvement in NGSO-FSS antenna directivity are feasible, improving the sidelobes and creating nulls.

The antenna sidelobes of horizontal flat plate antennas could be improved if the flat plate is replaced with a pyramidal structure with a flat top. All faces would not be active simultaneously, only those with adequate visibility in the direction of the satellite. Flat plate antennas produce the best performance when the beam is directed perpendicular to the plate, and the worst performance when the beam is tilted at a large angle. A pyramidal antenna structure would allow a smaller beam tilt angle when the beam is at the lowest elevation.

Electrically-steered phased array antennas, such as those Teledesic plans to use, can employ advanced signal processing to create nulls in a particular direction. These nulls could then be pointed at any DEMS transmitter that is near enough to cause interference. There are three kinds of antenna nulls that are technical feasible. First, permanently fixed nulls are always pointed in a specific predetermined direction and must be installed with the null pointing toward the interferer. Second, steerable nulls are under software control and can be pointed in the necessary directions at the time of installation. Finally, adaptive nulling or adaptive signal cancellation involves signal processing by circuitry in the receiver to cancel the unwanted signal.

Perhaps the simplest way to mitigate interference using antenna techniques is the use of a slightly larger dish antenna in the NGSO-FSS earth station. A slightly larger antenna offers improvement in link margins in two ways. First, a larger antenna has more on-axis gain which increases the signal level of the wanted signal. Second, it also has lower sidelobe gain, which decreases the signal level of the unwanted signal. As has been shown separately, a small increase in antenna diameter can substantially improve the NGSO-FSS link margin.

Frequency Separation, Coding and Filtering

Frequency separation is a traditional approach based on use of a channel plan and the assignment of different channels to nearby users whose systems are not physically shielded from one another. However, the Teledesic design, which employs a single 500 MHz wideband channel, may not be able to take advantage of this method.

The use of a channel plan allows different licensees and different services to share a co-primary frequency band at a location in a flexible, informal manner according to user needs, rather than by means of a rigid band segmentation plan.

Thus, for example, Section 101.147 of the FCC's Rules contains a variety of channel plans for various parts of the microwave radio spectrum. Similarly, Section 25.211(a) contains a channel plan for video transmission from C-band satellites, because this band is also used by terrestrial microwave systems. This channel plan was intended to minimize interference with microwave operations that conform to the channel plan in Section 101.147(h).

The Commission could similarly develop a channel plan for NGSO-FSS operations in the 18.8-19.3 GHz band that will allow both terrestrial microwave and NGSO-FSS licensees to use the portion of the band that they need in the place where they need it. The channel plan for 18 GHz terrestrial users in Section 101.147(r) serves as a starting point for such a NGSO-FSS channel plan. In this way, Teledesic could avoid the 100 MHz of DEMS spectrum in areas where DEMS transmitters are located, but continue to operate on the remaining 400 MHz of NGSO-FSS spectrum in those areas. In contrast, Teledesic seems to be arguing that a single unchannelized 500 MHz wideband radio channel, such as embodied in its current design, might be susceptible to interference across its entire 500 MHz from a DEMS transmitter operating on only a 10 MHz DEMS channel within the 500 MHz.

To the extent that Teledesic has not yet taken into account such a channel plan in their system design, there would appear to be sufficient time to modify such designs; Teledesic has reported that its design at this time is still entirely on paper, with no hardware development.

Another approach that could be employed to mitigate interference from narrow band DEMS signals into Teledesic's wideband signal is direct sequence pseudorandom coding. This approach, commonly used in spread spectrum technologies, has the effect of spreading the unwanted narrowband signal so that it is treated as very low power noise. In view of Teledesic's very wide bandwidth and the relatively narrow bandwidth of DEMS systems, such an approach may be appropriate here. An alternative and perhaps simpler approach would be the installation of narrow band notch filters at Teledesic's receivers.

This lack of maturity in the Teledesic design offers an opportunity for Teledesic to modify its technologies and amend its application so as to improve frequency sharing and mitigate interference with respect to both DEMS and point-to-point microwave systems. For example, in the two and one half years since Teledesic's application was submitted, discrete multitone modulation techniques have emerged that transmit a "comb" of multiple carriers. This approach, and a related approach known as OFDM or COFDM being used in Europe for digital broadcasting, allows real-time adaptation of the modulation parameters to avoid impaired portions of the spectrum. Moreover, the recently-filed Motorola M-Star system application appears to employ a design that "permits considerable flexibility in the channelization within the uplink and downlink bands." M-Star Application, p. 35.

In simple terms, this means that the proposed Teledesic design of a single 500 MHz wideband transponder is unique in the satellite communications world for being "unfriendly" to sharing its spectrum with co-primary terrestrial users, especially since the Teledesic design does not support frequency separation, nor employ filtering techniques or coding which takes advantage of the narrow bandwidth of DEMS signals compared to the proposed Teledesic downlink bandwidth. In contrast, both older C-band satellite systems and the newer M-Star system have been designed with frequency separation as an element of spectrum sharing.

CERTIFICATE OF SERVICE

I, James H. Barker, hereby certify that on this 27th day of August, 1997, true and correct copies of the foregoing were served by hand-delivery (*) or by U.S. mail, postage prepaid, on the following parties:

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